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Variation in Epidermal Color of Certain Species of Najades Inhabiting the Upper Ohio Drainage and their Corresponding Ones in L. Erie.

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I.—Introductory Statement of the Problem.

This paper is a continuation of the study of the color problem in certain species of Najades, first begun with an account of the variation in nacreous color in the same species. (4). Besides the major object as indicated in the title, now as previously an effort will be made to show how the standard scientific Color Nomenclature of Ridgeway, (14), may be applied to the corresponding descriptive characters of the species of Najades concerned. Again, as it has already been shown that changes in the morphological features of shells parallel changes in the accompanying physical conditions under which they are found, (1,2), effort will be made to show that in the epidermis of mussel shells, as well as in the nacre, changes in color which may be similarly associated take place.

The subject of the epidermal color of mussel shells does not seem to have been made the subject of extended investigation. v. Huber, (6), in studying some European and unrelated species remarks that the epidermis of river forms is generally brown, but at times a dirty green. Juveniles found in a subterranean canal were greenish in color, becoming black with age. v. Sell (15) observed that the lake variety of *Unio pictorum* often had a green coloring, (or rays), posteriorly, which was lacking in river forms of the same species. v. Israel, (7), noted that the males of *Unio crassus* were often reddish, while the females were gray. Marshall, (9), states that "as a rule it may be said that the color of very young specimens when not affected by foreign substances in the water is a light or olive gray in the growing shell, gradually assuming the colors by which it is known in the adult state." It is known

generally also that the shells of certain species at least blacken with age, but some effort has been made to ascribe this blackening in part to extraneous influences. Hay, (5), studied *U. tumidus* and *U. pictorum* from the Ouse and Foss Rivers in England. The Foss river had the more natural conditions, a bottom of mud, abundant aquatic vegetation, a gentler current, and received less polluting material than the Ouse. Its shells were lustrous and with a bright nacre. The Ouse River was wider, had a superabundance of mud in the bottom, and the shells in it were eroded, due either to the rapidity of the current or dissolved CO_2 in the water. The shells from this stream were dark or dead brown in color, erosion of the epidermis was considerably advanced, and the pearliness of the nacre was dull, possibly because this stream received the greater abundance and variety of drainage material. Hey believed the differences in coloration observed to be due the amount of such substances received. We may add here in order the observations of two experienced students of the Najades; Messrs. Calvin Goodrich of Toledo, Ohio, and V. S. Frierson, Frierson, La., as kindly given the writer in correspondence.

"Shells of the same species vary in color of epidermis in different streams, sometimes in the same stream under variations of environment. For example, the shells in the pools of Roche de Boeuf rapids, Maumee River are rough and dull hued. They are most of them covered with limy deposits and blotched with some black material which after removal leaves the shells little improved in appearance. The Miami and Erie Canal, upon the bank above these rapids, is fed from the Maumee 7 miles above. The shells of the canal are smooth, polished, often with a sheen like silk and lighter of color. The shells off Catawba Island, Ottawa Co., Ohio, are a bright, shining lot; those in La Plasaince bay, at the west end of the Lake, much dulled by comparison. The La Plaisance shells seem to be abraded by sand; those of Catawba Island escaping this treatment. On the north shore, many of the shells are stained with black and roughened with lime. Algæ, lime, sewage, vegetable growths and mineral matter of one kind and another appear to affect the color of the epidermis. I suppose light has some share in the business. You have no doubt, noticed that the older specimens of the museums show a distinct modification in color." . . . "There is near me a lake one quarter of a mile wide, two miles long, five to twenty feet deep. It is really

the old bed of a stream defunct several years ago. But the small streams which feed this lake and which cease to flow during droughts both produce an abundant crop of *Anodons*. Now in the lake, these grow to a large size, much inflated, smooth, somewhat rayed, brightly colored. But in the pools of the headwaters, creeks ten to fifteen feet deep, thirty feet wide, covered with trees, full of decaying leaves and black mud, grow shells elongate, compressed, rough, black and hardly to be differentiated from *Unio comptodon* by its external appearance. Yet they are no doubt the same species, or *no doubt frequently mother and daughter. This is environment.*"

Following the clues given in the foregoing, effort will be made in this paper to throw light on the following problems connected with the color of the epidermis in the species of Najades dealt with:

1. *In those species commonly assigned more than one epidermal color to determine as far as possible the relative prevalence of each color in all the shells as a whole, and the difference between L. Erie and Upper Ohio shells in this regard.*

2. (*a.*) *To ascertain whether any change in epidermal color takes place going down stream, both in the rivers and in their tributaries and to learn whether in any of the species a particular shade of the described epidermal color is peculiar to the body of water concerned.*

(*b.*) *To study the prevalence and qualities of the rays of the epidermis under conditions indicated for this and the preceding problem.*

3. *As a partial check on problems one and two as well as for their own biological interest to show,* (*a*) *any relation existing between the epidermal colors and the estimated age of the animals;* (*b*) *any association of the epidermal colors with their sex.*

II.—List of Species Used.

LAKE ERIE	UPPER OHIO DRAINAGE
Fusconaja flava parvula, Grier	*Fusconaja flava, Rafinesque.*
Amblema plicata, Say.	*Amblema costata, Rafinesque.*
Pleurobema obliquum pauperculum, Simpson	*Pleurobema obliquum coccineum, Conrad.*
Elliptio dilatatus sterkii, Grier	*Elliptio dilatatus, Raf.*
Symphynota costata eriganensis, Grier	*Symphynota costata, Raf.*
Anodonta grandis footiana, Lea.	*Anodonta grandis, Say.*
Paraptera fragilis, Raf.	*Parapiera fragilis, Raf.*
Proptera alata, Say.	*Propiera alata, Say.*
Anodontoides ferrussacianus subcylindricus, Lea.	*Anodontoides ferussacianus, Lea.*
Eurynia recta, Lamarck.	*Eurynia recta latissima, Rafinesque.*

Lampsilis luteola rosacea, Dekay. *Lampsilis luteola, Lamarck.*
Lampsilis ovata canadensis, Lea. *Lampsilis ovata ventricosa, Lamarck.*

The accompanying map, and list of localities as given in Plate III showing collecting stations will give some idea of their distribution in the Upper Ohio Drainage and L. Erie. The material used was collected by Dr. A. E. Ortmann over a number of years, (1903-07), in Western Pennsylvania and L. Erie, or secured by him in smaller amount as exchanges. Dr. Ortmann, besides suggesting the value of an introductory study to the color problem in Najades, has done everything in his power to assist the investigation, for which data was obtained at the Carnegie Museum in Pittsburgh. I am indebted to Dr. W. J. Holland, Director, for the freest use of the Museum's facilities in connection.

III.—Physical Conditions and type of Mussel Fauna.

The type of Mussel Fauna has already been admirably treated in papers by Walker (18) and Ortmann, (10-13 inclus.). These and the physical conditions concerned have already been summarized by the writer elsewhere (1); those for L. Erie being ably stated by Jennings, (8), and for the Upper Ohio Drainage in the Water Supply Papers of the U. S. Geological Survey.* At this point we may conveniently add Simpson's observations on the type of Mussel Fauna concerned particularly with regard to the problem we are dealing with. (16). "Species from the Mississippi Valley are more richly colored internally and externally than those of any other part of the globe. . . . All the Mississippi Valley species of Najades that have entered the St. Lawrence or any part of the Atlantic Drainage area have become changed . . . the nacre losing its brilliancy; instead of the bright epidermis often painted beautifully with rays in wonderful patterns, rich greens, yellows, olives we have mostly dull, livid, ashy, rusty reddish or brownish exteriors." Simpson did not believe these changes were due in any measure to climate or colder water, for the shells reach a similar development elsewhere. He further remarks that the changes in form, size and coloring have led students to create new species and varieties for what were originally Mississippi Valley shells. For sake of convenience however, the outstanding

* See Horton, T. H., Hall, M. R., Bolster, R. H. Leighton, M. D. "Surface Water Supply of the United States 1907–08. Part III Ohio River Basin, p. 29, 35, 47. Water Supply papers, U. S. G. S.

points concerning the physical conditions are given in the following contrasting columns.

LAKE ERIE	UPPER OHIO DRAINAGE
Water colder than in Upper Ohio but with more even regulation of temperature. Currents much less rapid than in streams; less agitated, except by very moderate currents carrying but little sediment. Bottom of pebbles or sand or mixture of these depending on region of lake, with coarser sediment derived from wear of land. Temperature conditions favor a more uniform production of food if in less abundance. Water is more highly alkaline than that of Upper Ohio Drainage.	*Waier warmer, but with greater extremes of temperature to face. Streams more rapid than current of L. Erie; greater agitation, frequent falls and rapids, short stretches of quiet pools. Rivers carry a load of debris moving quickly over the bottom which consists of mud, glacial fill, cobbles. Food conditions (due to extremes of temperature), are less stable, even if at times food is more abundant.*

Walker, (18) observes that L. Erie shells as a whole have brighter, (clearer) colors than their fellows of the Upper Ohio Drainage, are exceptionally polished, and otherwise characterized in distinction by their well developed lines of growth.

IV.—METHOD.

Before attempting the study of the shells, the epidermis of each was lightly scrubbed with a moderately stiff brush to remove any sediment, etc., adhering to it. Care was taken not to injure the epidermis in any way. Shells so badly eroded that a positive determination of nacre color was impossible were ignored in further study. The method pursued in the study of variation in epidermal color was largely that used in the investigation of nacreous color. (4). Here as with the nacreous colors, the epidermal colors did not lend themselves to the determination of any well defined color pattern. The problem is even more complicated in the latter, since a large number of different colors may be represented in the epidermis, due either to inherent causes or as the result of the interaction, as we shall see is probable, with the environment. To simplify matters to a stage where the problem could be grappled with, at least two colors, obtained by comparison with the standard colors of Ridgeway (14), were recorded for each shell. Following the clue cited from Marshall's paper, the first, (or primary), of these two colors was that, which by its lighter hues, distribution and relation to the other, (secondary) one taken was evidently the

present if not the original (juvenile) ground color of the entire shell. In most cases this color was confined to the anterior and inferior portions of the shell. The secondary color was that most evident on the superior and posterior portions. If present at all, it was usually, but not always darker than the primary color from which it was derived, and general observation showed that the regions of the shell where it was found, to be the place of transition from the primary color to it, whether to lighter or darker shades. Where there seemed to be doubtful relationships between these two recorded colors, two or three additional ones were taken for the purpose of tracing genetic relationship in the sequence of color changes. The colors then judged most to match the Ridgeway Standard Colors were then written in figuring books opposite calculatings made for the morphological features of each shell. Only one color was usually taken in consideration when effort was made to trace the sequence of change of color, but in view of the fact that color variation might be traceable as stated above to various influences, it was thought well to possess data which would serve to balance the conclusions. In Pl. III, (whose synthesis is afterwards described), two colors are given, the first is the secondary color; where only one is given, it represents the sole color determinable. Further, as the specific descriptions given of some of the shells indicate that the umbo may be lighter colored than the rest of the shell, some confusion may arise when in carrying the writers scheme in mind, it is observed that in Pl. III some of the secondary colors are lighter than the primary ones, as obtained by the above procedure. The general plan when the tables of distribution of color were prepared, was to give preference to that color most impressing the eye with its preponderance or vividness in the epidermis.

The prevailing color then being alone taken into consideration for the calculations, tables were prepared in the following way. Where a large number of shells from one locality were concerned, it was the usual practice to group all shells of a closely similar epidermal color and compare as a whole with the shades given in Ridgeway. By this means a general or average hue was obtained, not accurate of course for every shell, but very convenient in determining the "relative colors" of the shells at that locality to ones near it, above or below in the particular body of water. As a rule these relative colors were taken from a fairly large number of shells, although a lack of material often compelled the use of

smaller numbers. Against such treatment however was the check of a separate color comparison for each shell. By means of this method, it was possible to determine for each species shades of epidermal color peculiar to the locality where the shells had been collected, and this being done, charts were prepared showing the sequence of color changes passing down stream, or the distribution in different parts of the same body of water. This data, in consolidated form is presented in Pl. III. Even by this process of condensation, a very large number of colors was obtained for each species, making it imperative to simplify further in order that the evidence for the relative prevalence of different epidermal colors in those species where more than one was described might be rendered more intelligible for report. Just as the systematist for rough descriptive purposes has picked out a number of the more prominent epidermal colors of each species, the writer, following largely Simpsons Descriptive Catalogue of the Naiades, (17), chose from the previously prepared charts the ten to thirty leading colors, (primary or secondary), in the epidermal colors of each species to which the large majority of the rest could be assigned. Percentages of these leading colors were then calculated for each species in the bodies of water, drainages, groups of drainages in which they were found, as best seemed to throw light on the problems to be attacked. While all recorded shades in a large number of cases would not conform to this treatment, they represent percentages in the extreme minority, and may be inferred to exist in those species where the tables of Distribution of Colors as a Whole does not add up to 100%. Strictly speaking, even this comparatively large number of "leading colors" could have been condensed to a smaller number, but the larger number was necessary in order that certain close distinctions in the colors of the epidermis for the purposes of the investigation might be made, for example, between the colors of shells from a river and those from its tributaries. In the discussion of any particular body of water, however, the leading colors given, represent my reduction to lowest terms of the colors represented in it.

Data on the sex of the animal, prevalence of rays, etc., were taken at the time color comparisons were made. So far as observations on epidermal color as associated with the sex of the animal are concerned, the small number of shells on which they are based is explained by the fact that the specimens were collected before Dr.

Ortmann's discovery that the sex of the animal is readily determinable from the structure of the gills. In associating epidermal color with the estimated age of the animal, the latter was determined by counting the number of winter rings on the shell. As I have given elsewhere some discussion of the accuracy and inaccuracy of the results attending this method, (4), it need only be stated that the conclusion staken from the Upper Ohio shells were checked by similar ones from the L. Erie specimens, where this method of estimating the age is less objectionable. Moreover, the conclusions are so general in character as not to be readily affected by mistakes in the age of a very small minority. Pressure of these observations, and also the fact that as a whole few differences could be observed in the texture of the epidermis of shells, lead me to disregard the latter character altogether.

V.—Results.

Each species is dealt with separately, there first being given in parallel columns:

(a.) Descriptive material concerning epidermal color as taken from Simpson.

(b.) The equivalent in the writers opinion of the Simpson Colors in terms of the Ridgeway Color Nomenclature.

It is felt that by this arrangement and the inferences to be drawn from the names of the Ridgeway Colors themselves, it will be possible for the reader to sufficiently understand the terminology used as to convey the principles this paper hopes to make clear. Additionally the writer has endeavored to supplement this by the use of such generalized color terms as he could command. For the sake of greater clarity there are also given latterly in the Ridgeway column the peculiar shades of the L. Erie shells, although these are by the convenient and arbitrary arrangement adopted, but varieties of the hues given in the tables dealing with "Distribution of Colors as a Whole," in which effort is made to throw light upon the first problem stated. There then follow tables giving the relative distribution of epidermal colors in the Upper Ohio Drainage as a whole; and separately, the component drainages. The same is done for L. Erie and its various collecting stations. Additionally, remarks largely in explanation of Pl. III, (chart illustrating sequence of epidermal color changes), and on the prevalence and quality of the rays of the epidermis. The dis-

cussion of each species terminates with the evidence for association of particular hues of the epidermis with the estimated age of the animal and its sex.

1.—*Fusconaja flava*

SIMPSON	RIDGEWAY
Brown	Brownish Olive.
Greenish Brown	Ecru Olive, Yellowish Citrine
Brownish, Blackish, (when old)	Bister, Dresden Brown, Sepia, Carob Brown, Seal Brown.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (275 shells).

Dresden Brown	40%
Bister	20%
Brownish Olive	20%
Ecru Olive	10%
Sepia	10%

Distribution of Colors as a Whole in Upper Ohio Drainage. (225 shells).

Dresden Brown	40%
Bister	20%
Brownish Olive	20%
Sepia	10%
Ecru Olive	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries, etc.

	Alle'ny Tribs.	*Alle'ny River*	*Mon'g. Tribs.*	*Mon'g. River*	*Ohio River*	*Ohio Tribs.*
Dresden Brown	25%	25%	20%	20%	20%	
Bister	25%	25%			20%	50%
Sepia	50%	25%		20%	20%	
Ecru Olive			20%	20%	20%	
Seal Brown		25%				
Yellowish Citrine			40%			25%
Brownish Olive			20%	40%	20%	25%

Distribution of Colors as a Whole in L. Erie (50 shells).

Carob Brown	30%
Yellowish Citrine	20%
Seal Brown	20%
Dresden Brown	20%
Ecru Olive	10%

Distribution in L. Erie,—localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle Bay*	*Maumee R. Drain*
Carob Brown				66%
Yellowish Citrine	40%	25%		33%
Seal Brown			25%	

Dresden	20%		25%
Ecru Olive	25%	25%	25%
Tawney Olive	15%	50%	25%

Deductions from Tables of Percentages and Pl. III.

Yellowish greens are more abundant in L. Erie than in the Upper Ohio Drainage; the browns of L. Erie are of a reddish variety, those of the Upper Ohio darker, towards black. Generally, the shells of L. Erie are seen to be lighter in color.

In the Upper Ohio Drainage.

With few exceptions, the color of the epidermis is darker in the rivers than in their tributaries, and darker at the lower stations of the latter than at the upper. This applies to both primary and secondary colors. At Crooked Creek, Creekside, the primary color is a sort of Greenish Olive, but lower down at Rosston, this is succeeded by a darker Yellowish Olive. The secondary colors has deepened to a Seal Brown, acquiring at a near station on the Allegheny, Kelley, a Cinnamon Brown, while the primary color has deepened to a Brownish Olive.* The same type of change may be traced down the latter stream, as well as from the tributaries of the Monongahela, Dunkard and 10 mi. Creeks to that body of water. As the Ohio River is approached, epidermal color becomes darker and darker. Some characteristic primary colors of streams are Brownish Olive for the Allegheny; Greenish Olive for Crooked Creek.

In L. Erie.

The shells at Presque Isle have less Yellowish Green than those at La Plaisance Bay. Cedar Point is characterized by a large percentage of Tawney Olive colors, while the Maumee River draining into L. Erie has an excessive proportion of brown among its shells. In this as well as in other species, different parts of the same collecting locality, such as the various parts of Presque Isle Bay, are apt to show a peculiarly distinctive epidermal color.

Rays of Epidermis.

According to Simpson, this shell is faintly rayed in the young state. 29 of 275 shells had rays, mostly medium in size. My observations indicated that they persisted in some until the 11th year. Raying was most abundant in specimens from the small rivers and creeks, rather than in the larger rivers and lakes. Their prevailing colors were olive, yellowish or darker green.

* Names of Ridgeway Colors are capitalized in this paper.

Relation of Epidermal Color to Estimated Age of Animals.

Young shells of this species in the Upper Ohio Drainage are mostly Yellowish Brown; in L. Erie, mostly Brownish Green. In the former they become brownish or black rapidly as early as the 3rd and after the 5th–8th year, where in my material yellowish brown was represented in only 1-8 of the shells. Yellowish brown and brown were nearly equally represented in L. Erie shells. No one color or group of colors seemed peculiar to a given age except the deep browns and blacks of old age or advanced maturity.

Observation on Sex Correlative Coloration as Related to Epidermal Color.

Older males are characterized by a Seal Brown color, younger by more of a greenish yellow. Females have larger proportions of more vivid Reddish Brown colors, while the younger ones tend toward Buffy Olive Colors.

2—*Amblema costata*

SIMPSON	RIDGEWAY
Yellowish green	Yellowish Olive. Yellowish Citrine, Dull Citrine.
Brown or blackish	Bister, Mars Brown, Prouts Brown, Dresden Brown

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (185 shells).

Yellowish Olive	40%
Prouts Brown	20%
Mars Brown	20%
Dresden Brown	10%
Bister	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (107 shells).

Prouts Brown	30%
Yellowish Citrine	20%
Dresden Brown	20%
Bister	20%
Buffy Citrine	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Alle'ny River*	*Beaver Tribs.*	*Beaver River*	*Ohio River*
Prouts Brown	40%	60%	32%	33%	25%
Yellowish Citrine	20%		37%	33%	
Dresden Brown	40%		12%		50%
Bister		40%	6%		25%
Buffy Citrine			12%	33%	

Distribution of Colors as a Whole in L. Erie.

Prouts Brown	30%
Dull Citrine	20%
Yellowish Citrine	20%
Mars Brown	20%
Yellowish Olive	10%

Distribution in L. Erie—Localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle*
Prouts Brown	50%		
Dull Citrine	25%	25%	25%
Yellowish Citrine		25%	25%
Mars Brown	25%		
Yellowish Olive		50%	50%

Deductions from Tables of Percentages and Pl. III.

Yellowish and greenish hues are most abundant in L. Erie, showing that shells there have brighter colors. There are more buffy or darker colors in the Upper Ohio Drainage, where reddish browns are characteristic.

In the Upper Ohio Drainage.

We observe from the above tables that the darker browns are more abundant in the rivers, the lighter colors in the tributary streams. Primary and secondary colors are observed to darken descending the Allegheny, Shenango Rivers and French Creek. Characteristic stream colors for this and most of the species of shells dealt with are best given in Pl. III. In the tributaries the colors are usually greenish yellow hues. Characteristic stream colors are yellowish green. (Citrine), in the Allegheny, greener shades of Citrine in French Creek, buff varieties of this in the Shenango, olive varieties in the Mahoning. At the nearest approach of these streams to the Ohio the shells are found to blacken.

In L. Erie.

Presque Isle shells have yellow colors, La Plaisance Bay, brown. Those of Cedar Point are more of a Yellowish Olive.

Rays of Epidermis.

Simpson reports no rays for this species. 4 of 107 shells were rayed, persisting at least until the 10th year. The rayed shells were L. Erie specimens. The prevailing color was Greenish Olive.

Relation of Epidermal Color to Estimated Age of Animal.

Juvenile shells are mostly yellowish in the Upper Ohio, those

from L. Erie are green. L. Erie shells have also a larger proportion of green with advancing age. Shells in both become black and brownish with age, but in L. Erie later than in the Upper Ohio. These old age colors appear at 4 years and are complete at 9. No one color or group of colors was found to be peculiar of any age.

Observation on Sex-Correlative Coloration as Related to Epidermal Color (11 Shells.)

Young males are of a Buffy Olive color, becoming reddish brown with age. Females in youth are of a Yellowish Olive hue, becoming brownish red with age and tending to blacken.

3.—*Elliptio dilatatus*

Dull green, young shells	Buffy Citrine, Yellowish Citrine
Yellowish brown	Bister, Warm Sepia, Dresden Brown, Aniline Black, Chestnut, Cinnamon.
Darker, when old.	

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (561 shells.)

Bister	30%
Warm Sepia	20%
Dresden Brown	20%
Buffy Citrine	20%
Aniline Black	10%

Distribution of Colors as a Whole in the Upper Ohio Drainage (509 shells).

Bister	20%
Warm Sepia	20%
Dresden Brown	20%
Dresden Brown	20%
Seal Brown	20%
Brownish Olive	20%

Distribution of Colors as a Whole in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Alle'ny River*	*Mon'g Tribs.*	*Mon'g River*	*Ohio River*	*Beaver Tribs.*	*Beaver River*
Bister	22%	40%	25%	50%	25%	12%	
Warm Sepia	27%	20%	12%		25%	30%	25%
Dresden Brown	22%	40%			25%	12%	25%
Seal Brown	29%		25%		25%	12%	
Brownish Olive			37%	50%		33%	50%

Distribution of Colors as a Whole in L. Erie (52 shells).

Chestnut Brown	30%
Dresden Brown	20%
Cinnamon Brown	20%
Yellowish Citrine	20%
Aniline Black	10%

Distribution in L. Erie—Localities.

	La Plaisance	*Presque I.*	*Chautaugua L.*
Chestnut Brown		25%	25%
Dresden Brown	25%	25%	
Cinnamon Brown	25%		25%
Yellowish Citrine	50%	25%	25%
Brownish Olive		25%	25%

Deductions from Tables of Percentages and Pl. III.

L. Erie is seen to contain more yellow shells than the Upper Ohio Drainage, and its browns are of a lighter color. Black seems to be in a minority in the Upper Ohio Drainage.

In the Upper Ohio Drainage.

Here we observe there is a greater percentage of dark colors in the rivers than in the tributaries. A general darkening may be observed descending the Allegheny—the primary color, originally of an olive hue assuring brownish and buffy hues, while the secondary colors pass from light reddish brown shades to dark ones. A similar change may be observed in French Creek, the Shenango and Mahoning Rivers. A characteristic stream color of the latter is an olive shade; that of the Allegheny, a brown. For others see the combinations of primary and secondary colors presented presented on Pl. III.

Buffy primary colors characterize the Allegheny, Brownish Olive French Creek, Buffy Olive the Shenango, Olive the Mahoning.

In L. Erie.

La Plaisance Bay alone is represented by yellow colors to an appreciable amount, those of Presque Isle are prevailingly brown.

Chautauqua Lake stands out for the absence there of vivid reddish shades of brown.

Rays of Epidermis

Simpson—"often faintly rayed in young specimens"—32 of 509 shells were rayed. Rays may persist as late as the 14th year, and were most abundant in specimens from small rivers and creeks, were mostly medium in texture, and Greenish Olive was their most common color.

Relation of Epidermal Color to Estimated Age of Animal.

Dull green is more plentiful in the young of Upper Ohio shells, yellowish brown in those of L. Erie. Shells from the former darken rapidly after the 6th year, in the latter about the 8th. The mature

or old age colors of brown and black may begin at 3-4 years and be complete at 6. No one color or group of colors was found to be peculiar of any age.

Observation on Sex-Correlative Coloration as Related to Epidermal Color (15 shells).

Males have a larger proportion of clear brown colors, young males are largely brownish olive. Females are represented by larger proportions of reddish browns, young females being Buffy Olive.

4.—*Pleurobema obliquum coccineum*

SIMPSON	RIDGEWAY
Tawney or yellowish green when young.	Buffy Citrine
Brownish	Prouts Brown, Mummy Brown, Mars Brown, Aniline Black
Reddish Brown	Seal Brown, Warm Blackish Brown.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (263 shells.)

Prouts Brown	30%
Mummy Brown	30%
Mars Brown	20%
Buffy Citrine	10%
Aniline Black	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (247 shells).

Prouts Brown	30%
Mummy Brown	30%
Mars Brown	20%
Buffy Citrine	10%
Aniline Black	10%

Distribution of Color as a Whole in Upper Ohio Tributaries etc.

	Alleghney Tribs.	*Alleghney River*	*Beaver Tribs.*	*Beaver River*	*Tusca. River*
Prouts Brown	33%	25%	30%	25%	
Mummy Brown	35%	50%	30%	25%	75%
Mars Brown	15%	25%	25%	25%	
Buffy Citrine	10%		5%	25%	25%
Aniline Black	5%		10%		

Distribution of Colors as a Whole in L. Erie (16 shells).

Warm Blackish Brown	20%
Cinnamon Brown	20%
Buffy Citrine	20%

Seal Brown	20%
Buffy Citrine	10%
Aniline Black	10%

Distribution in L. Erie—Localities.

	La Plaisance Bay	*Presque Isle*
Warm Blackish Brown		50%
Cinnamon Brown	50%	
Buffy Citrine	50%	25%
Seal Brown		25%

Deductions from Tables of Percentages and Pl. III.

Again we find that the shells of L. Erie have lighter browns and greater percentages of yellow.

In the Upper Ohio Drainage

The darkening of both primary and secondary colors, (Yellowish Olive and light browns to Brownish Olive and dark browns) is observed descending stream in the Allegheny Shenango, Mahoning Rivers and French Creek. In many cases the darkening in secondary colors can only be traced from tributaries to rivers. Some characteristic primary stream colors are olive in the Allegheny, yellow or brownish olive in Crooked Creek, greenish or brownish yellow in the Shenango, Yellowish Olive in the Mahoning.

In L. Erie.

The shells of La Plaisance Bay are brownish yellow; those of Presque Isle are prevailingly blackish brown, like those of the Tuscarawas River in the Upper Ohio Drainage.

Rays of Epidermis.

Simpson—"shell rayed when young." 27 of 247 shells were rayed. persisting in some cases until the 14th year. In quality, these were finest in the largest rivers, medium in the small rivers and creeks, where they were also more abundant. Prevailing color was Greenish Olive.

Relation of Epidermal Color to Estimated Age of Animals.

With age, shells become reddish brown in the Upper Ohio Drainage. Data concerning L. Erie shells is fragmentary, but as a rule in both, brownish, tawney, and greenish hues decrease with age. Darkening occurs early, about the 4-5 year. Older shells are mostly reddish brown. No color or group of colors seemed peculiar to any given age.

Observation on Sex-Correlative Coloration as Related to Epidermal Color. (13 shells)

Older males have warm reddish brown colors; in youth, lighter yellows and olives are representative. Females have a greater tendency to blacken, and have darker colors throughout life.

5.—*Symphynota costata*

SIMPSON	RIDGEWAY
Yellowish Green	Buffy Citrine
Tawney	Brownish Olive
Brownish	Bister, Chestnut, Mars Brown, Prouts Brown, Mummy Brown.

Distribution of Colors in Upper Ohio Drainage and L. Erie (68 shells).

Bister	20%
Brownish Olive	20%
Buffy Citrine	20%
Chestnut	20%
Mars Brown	20%

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (47 shells.)

Warm Sepia	30%
Brownish Olive	20%
Buffy Olive	20%
Mummy Brown	20%
Bister	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Alle'ny River*	*Ohio River*	*Monong River*	*Beaver Tribs.*
Warm Sepia	50%	20%		25%	
Brownish Olive	12%	20%	25%	50%	37%
Buffy Olive	12%	20%	50%	25%	25%
Mummy Brown	12%	20%			25%
Bister	12%	20%	25%		13%

Distribution of Colors as a Whole in L. Erie (21 shells).

Buffy Citrine	40%
Chestnut	20%
Mars Brown	20%
Prouts Brown	10%
Mummy Brown	10%

Distribution in L. Erie—Localities.

	La Plaisance Bay	*Presque Isle*
Buffy Citrine	25%	
Chestnut	25%	50%
Mars Brown	25%	25%

Prouts Brown.....25%
Mummy Brown.....25%.....

Deductions from Tables of Percentages and Pl. III.

Light colors, (Buffy Olive), are apparently equivalent in the Upper Ohio Drainage and L. Erie, but the browns are deeper hued in the latter, much as in the preceding species.

In the Upper Ohio Drainage.

Shells from the rivers are darker than those from the tributaries. A partially incomplete series of darkening primary and secondary colors may be traced descending the Allegheny, Shenango, and Mahoning Rivers. This would be more complete had more material been available. Characteristic primary colors are Buffy ones for the Allegheny, Citrine for the Shenango. Due again to lack of material, there is no outstanding differences between the shells of the Monongahela and its Tributaries. Darkening of the epidermis occurs descending the Ohio.

In L. Erie

Presque Isle shells are distinguished from those of La Plaisance Bay by the abundance of browns, and the practical absence of yellow colors.

Rays of Epidermis

Simpson—"often rayed." 3 of 68 shells showed raying, in shells 9-12 years of age, and persisting at least until that age. The prevailing color of rays was greenish olive.

Relation of Epidermal Color to Estimated Age of Animal.

With age, the Chestnut or dark colors become in the majority. Darkening may occur as early as the 7-9 year, and seems complete at 15. "Greenish" is always a minority color. Darkening occurs less rapidly in L. Erie, and the percentage of yellows apparently increases with age in the Upper Ohio Drainage. Young shells were not plentiful among my material.

Observation on Sex-Correlative Coloration as Associated with Epidermal Color (6 shells).

Within the limits of the small number of shells considered, the males stand out for blackish colors with age, and Buffy Olives in youth. Females had lighter browns than males, and young specimens were Brownish Olives.

6.—*Anodonta grandis*

SIMPSON	RIDGEWAY
Greenish brown	Yellowish Olive, Olive Green
Brownish green	Brownish Olive, Ecru Olive
	Other Colors:
	Buffy Citrine, Varley Green, Straw Yellow, White.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (119 shells).

Brownish Olive	40%
Yellowish Olive	20%
Olive Green	20%
Ecru Olive	10%
Buffy Citrine	10%

Distribution of Color as a Whole in Upper Ohio Drainage (97 shells).

Brownish Olive	40%
Olive Green	20%
Saccardos Olive	20%
Ecru Olive	10%
Buffy Citrine	10%

Distribution of Colors in Upper Ohio Tributaries etc.

	Allegheny Tribs.	*Beaver Tribs.*	*Mgnong. Tribs.*
Brownish Olive	50%	25%	
Olive Green	25%		25%
Saccardos Olive	12%		25%
Ecru Olive	25%	25%	
Buffy Citrine	12%	25%	
Mummy Brown			50%

Distribution of Colors as a Whole in L. Erie and by localities.

	As a Whole	*La Plaisance Bay*	*Cedar Point*	*Presque Isle*
Brownish Olive	30%	25%	25%	25%
Ecru Olive	30%		50%	25%
Varley Green	20%			25%
Straw Yellow	10%	50%	25%	25%
White	10%	25%		

Deductions from Tables of Percentages and Pl. III.

The L. Erie shells may be distinguished from those of the Upper Ohio by the abundance of yellowish and greenish yellow tints, those of the latter being Brownish or Yellowish Olive.

In the Upper Ohio Drainage.

A darkening descending the Allegheny was observed in the scanty material at hand. This is more evident in French Creek

where an Olive hue is taken on, and to some extent is evident in the Shenango and the Mahoning Rivers. Characteristic primary colors are Yellowish Olive for the Shenango, and Varley, (bright) Green for the Mahoning. Shells from the Ohio are deeper in color than those from Raccoon Creek, a comparatively near tributary. The Allegheny Tribs. have the most Brownish Olive, the Monongahela Tribs. the most dark brown, greenish colors are most abundant in the Beaver Tribs.

In Lake Erie

Yellow colors predominate at La Plaisance Bay, Olive at Cedar Point and these are equivalent at Presque Isle.

Rays of Epidermis

Simpson—"rarely faintly rayed, but showing 3 broad dark rays on the posterior slope." Only a few specimens from creeks were noted. In these the rays were bright green and medium in texture. They were present at least until the 14th year.

Relation of Epidermal Color to Estimated Age of Animal.

In the Upper Ohio Drainage, Brownish rather than Yellowish Brown increases with age, but at old age, these colors seem to be equally prevalent. The old age colors of brown appear at 6-8 years in both groups of shells and may be complete at this age. L. Erie shells are mostly green at first. No colors seemed peculiar to any given age.

Observation on Sex-Correlative Coloration as associated with Epidermal Color. (8 shells)

In this small number of shells, males were distinguished by a preponderance of Olive colors; females ranged from yellowish green to brownish hues.

7.—Paraptera fragilis

SIMPSON	RIDGEWAY
Greenish yellow	Olive Lake, Deep Colonial Buff, Yellowish Citrine.
Pale Smoky brown	Brownish Olive, Buffy Olive.
Dark Colored	Ecru Olive.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (58 shells).

Ecru Olive.....30%
Deep Colonial Buff.....20%

Brownish Olive	20%
Olive Lake	20%
Buffy Olive	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (28 shells).

Ecru Olive	20%
Olive Lake	20%
Brownish Olive	20%
Buffy Olive	20%
Yellowish Citrine	20%

Distribution of Colors as a Whole in Upper Ohio Tributaries, and River.

	Allegheny River	*Ohio River*
Ecru Olive		20%
Olive Lake	25%	20%
Brownish Olive	50%	40%
Buffy Olive	25%	
Yellowish Citrine		20%

Distribution of Colors as a Whole in L. Erie (30 shells).

Deep Colonial Buff	30%
Brownish Olive	20%
Saccardos Olive	20%
Ecru Olive	20%
Grayish Olive	10%

Distribution of Colors in L. Erie—Localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle Bay*
Deep Colonial Buff	25%	50%	20%
Brownish Olive	25%		20%
Saccardos Olive	25%		
Ecru Olive	25%	25%	40%
Grayish Olive	25%		20%

Deductions from Tables of Percentages and Pl. III.

Shells from L. Erie are lighter than those from L. Erie although both possess many colors in common. Buff colors predominate in the former.

In the Upper Ohio Drainage

Shells darken, both primarily and secondarily in going down stream from the Allegheny to the Ohio. Olive Lake is a characteristic primary color for the former, Buffy Citrine for the latter.

In Lake Erie

Buff colors are in the lead at Cedar Point, Olive at Presque Isle, while Grayish Olive seems wanting at La Plaisance Bay.

Rays of Epidermis

Simpson "Often rayless, sometimes feebly rayed". 37 of 58 shells were rayed, the oldest age being 13. The texture of these from the lake was prevailingly fine those of the rivers medium. The most common color was a Dark Green.

Relation of Epidermal Colors to Estimated Age of Animals.

In youth, 1-2 of the shells are either Brown or Green. Most have become of a greenish hue about the 7th year. Green is more prominent in L. Erie shells. Old age colors may appear at 6, completely at 14 years. There appeared to be few if any completely dark colored specimens. No colors seemed to be peculiar to any given age.

Observation on Sex-Correlative Coloration as Associated with Epidermal Color. (5 shells).

In the small amount of L. Erie material only green colors seemed to characterize males, yellow, females.

8.—*Proptera alata*

SIMPSON	RIDGEWAY
Brownish	Mummy Brown, Buffy Brown, Bister, Light
Blackish	Brownish Olive
Olive Green	Buffy Citrine, Buffy Olive
Reddish	Dresden Brown.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (55 shells).

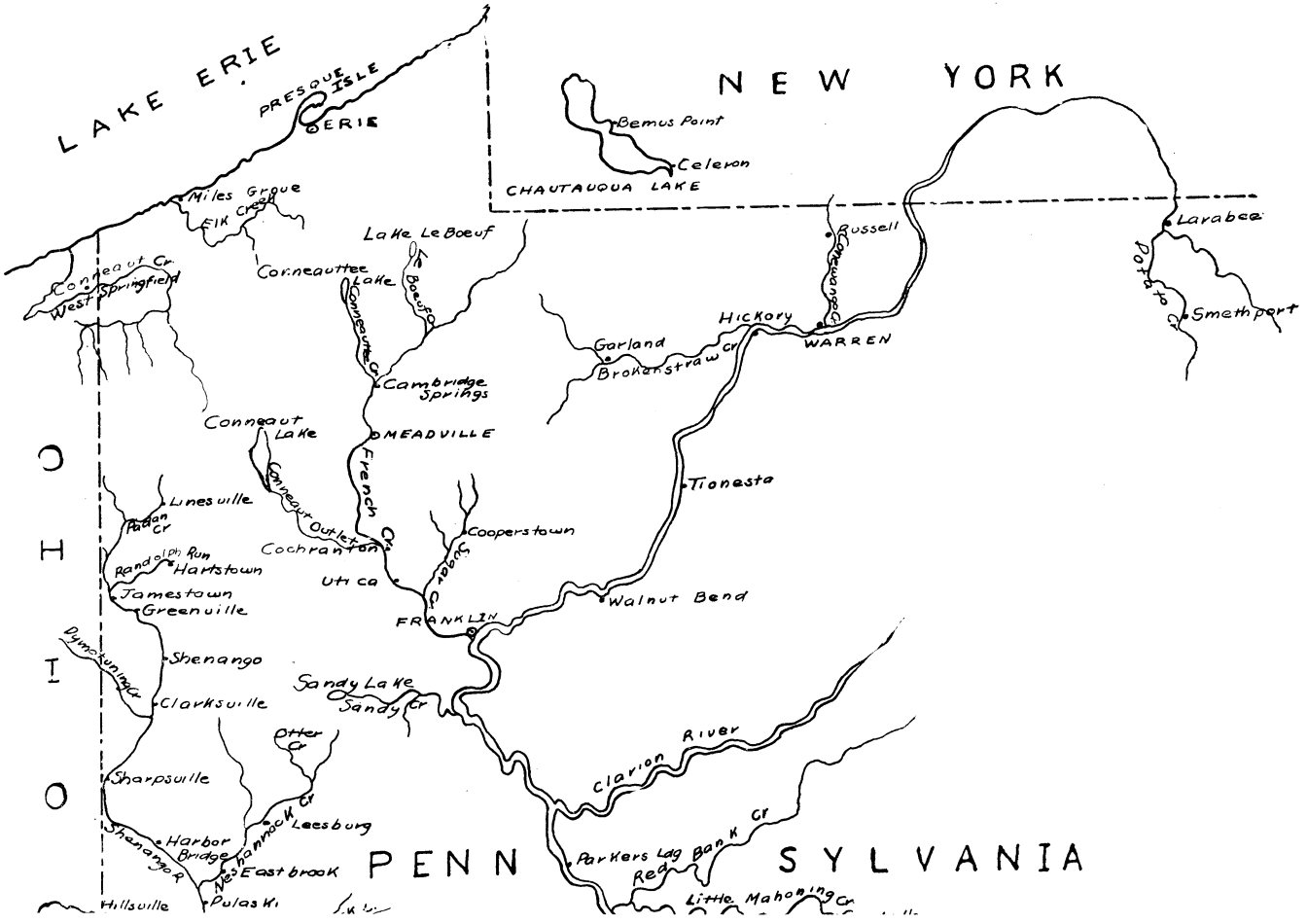
Buffy Citrine	30%
Mummy Brown	20%
Buffy Brown	20%
Bister	20%
Buffy Citrine	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (24 shells).

Olive	20%
Mummy Brown	20%
Buffy Olive	20%
Aniline Black	20%
Snuff Brown	10%
Saccardos Umber	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (24 shells).

Olive	20%
Mummy Brown	20%
Buffy Olive	20%


LAKE ERIE
PRESQUE ISLE
ERIE
NEW YORK
Bemus Point
Celeron
CHAUTAUQUA LAKE
Miles Grove
ELK Creek
Lake LeBoeuf
Russell
Larabee
Conneaut Cr.
West Springfield
Conneauttee Lake
Conneauttee Cr.
Boeuf Cr.
Conewango Cr.
Potter Cr.
Smethport
Garland
Brokenstraw Cr.
Hickory
WARREN
Cambridge Springs
Conneaut Lake
MEADVILLE
Conneaut Outlet
French Cr.
Tionesta
Linesville
Padan Cr.
Cochranton
Cooperstown
Randolph Run
Hartstown
Utica
Jamestown
Greenville
FRANKLIN
Walnut Bend
Shenango
Clarksville
Sandy Lake
Sandy Cr.
Otter Cr.
Clarion River
Sharpsville
Harbor Bridge
Yellow Creek
Leesburg
Shenango R.
New Eastbrook
PENNSYLVANIA
Parkers Landing
Redbank Cr.
Hillsville
Pulaski
Little Mahoning Cr.

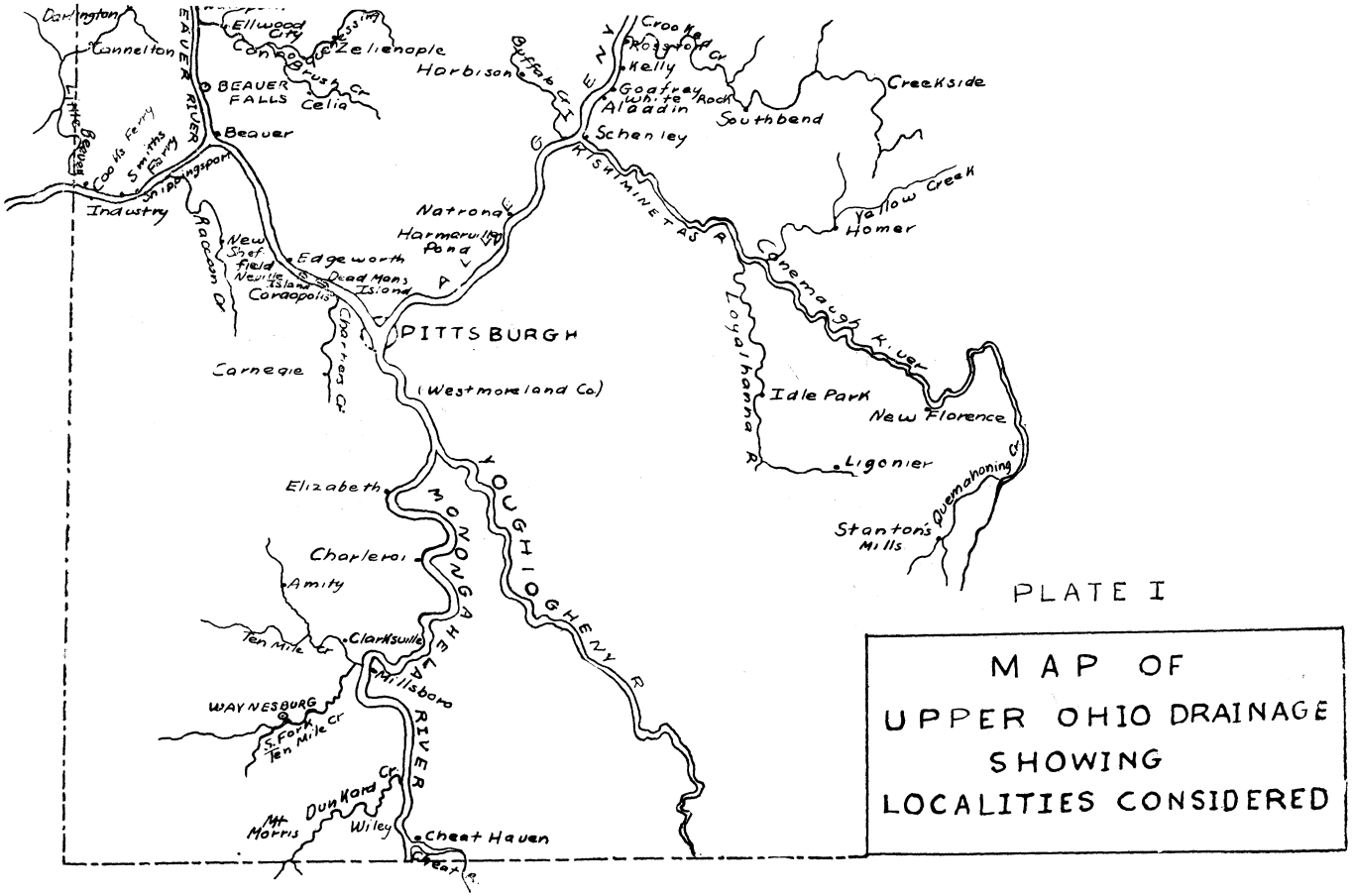


PLATE I.—GRIER ON VARIATION OF EPIDERMAL COLOR OF CERTAIN SPECIES OF NAJADES.

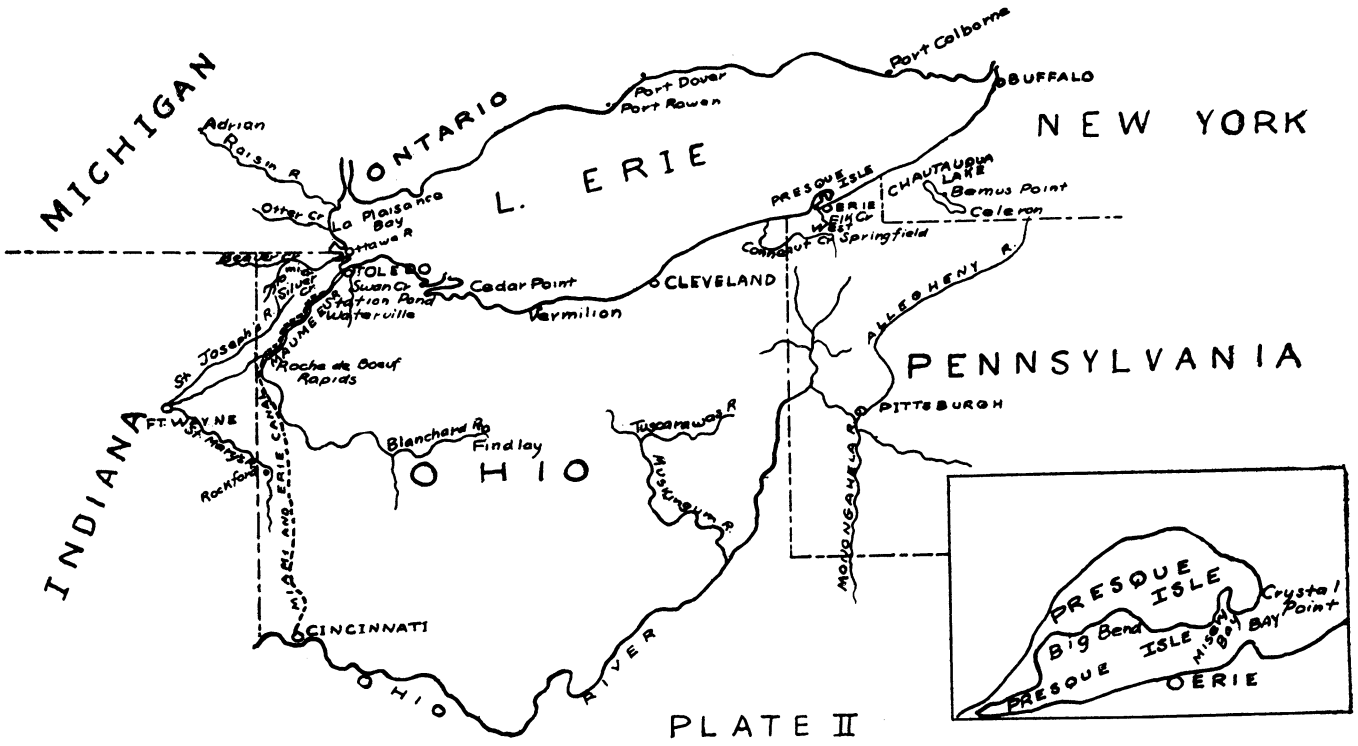


PLATE II

MAP OF LAKE ERIE AND ADJACENT REGIONS

SHOWING LOCALITIES CONSIDERED

Aniline Black	20%
Snuff Brown	10%
Saccardos Umber	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries.

	Alle ny Riv.	*Monong. Riv.*	*Ohio Riv.*
Olive		25%	25%
Mummy Brown	50%	25%	
Buffy Olive			25%
Aniline Black		25%	25%
Snuff Brown	25%	25%	25%
Saccardos Umber	25%		

Distribution of Colors as a Whole in L. Erie (31 shells).

Light Brownish Olive	30%
Buffy Citrine	20%
Buffy Olive	20%
Mummy Brown	20%
Dresden Brown	10%

Distribution in L. Erie—Localities.

	Cedar Point	*Presque Isle*	*Maumee River*
Light Brownish Olive	25%	25%	
Buffy Citrine	25%	25%	25%
Buffy Olive	25%		25%
Mummy Brown	25%	25%	25%
Dresden Brown		25%	25%

Deductions from Tables of Percentages and Pl. III.

In this species also it is noted that the colors of the shells from the Upper Ohio Drainage are darker. The browns of L. Erie are of reddish hues, those from the Upper Ohio Drainage more blackish in nature. L. Erie has also a larger percentage of olive colors.

In the Upper Ohio Drainage

A darkening of colors from olive to brown may be traced down the Allegheny and in primary colors, (olive to brown), from the Monongahela into the Ohio. Darkening from Brown to Blackish is characteristic of a large part of the Ohio. Saccardos Umber would be a secondary color for the Allegheny; Buffy Olive for the Ohio. Other characteristic colors are indicated in the tables given above.

In Lake Erie

Here the shells possess a brownish olive not found in the shells of the Maumee River which empties into it. Buffy Olive colors are peculiar to Cedar Point shells, while the deeper browns belong to Presque Isle shells.

Rays of Epidermis

Simpson mentions no rays in this species. However 34 of 55 shells were found to be rayed, and rays persist at least until the 15th year. In this case, lake shells had coarser rays than those of the river, although there were a large number of fine rayed specimens in both. Light green was the prevailing color.

Relation of Epidermal Color to Estimated Age of Animal.

The percentages of green colors tend to increase with age in both Upper Ohio and L. Erie, while brown, the other juvenile color, decreases with age. Color changes take place about the 12th-14th year, old age colors may appear as early as 10 years, more fully at 12. Blacks apparently decrease with age in the Upper Ohio, but this is based on fragmentary data. No color or group of colors seemed peculiar to any given age.

Observation on Sex-Correlative Coloration as related to Epidermal Color. (5 shells).

Males are more largely green, females brownish yellow.

9.—*Anodontoides ferussacianus*

SIMPSON	RIDGEWAY
Greenish	Hellebore green; *other colors:* Buffy Olive Brownish Olive, Yellowish Olive, Deep Olive Isabella Color.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (69 shells).

Buffy Olive	30%
Brownish Olive	20%
Yellowish Olive	20%
Deep Olive	20%
Olive	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (45 shells.

Buffy Citrine	30%
Brownish Olive	20%
Isabella Color	20%
Hellebore Green	20%
Buffy Olive	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Beaver Tribs.*
Buffy Citrine	20%	20%
Brownish Olive	60%	20%

Isabella Color	20%
Hellebore Green	20%
Buffy Olive	20% 20%

Distribution of Colors as a Whole in L. Erie (24 shells).

Brownish Olive	30%
Chestnut Brown	30%
Yellowish Olive	20%
Deep Olive	10%
Hellebore Green	10%

Distribution in L. Erie, with that in other localities to be compared.

	Presque Isle	*Maumee River*	*Conneaut Lake*
Brownish Olive	40%	50%	
Chestnut Brown	20%		50%
Yellowish Olive	20%		
Deep Olive	20%	25%	25%
Hellebore Green		25%	25%

Deductions from Tables of Percentages etc.

Shells of L. Erie are olive or yellowish, whereas those of the Upper Ohio are brownish or buffy.

In the Upper Ohio

It is observed that shells become more buffy in color in the lower stretches of French Creek. A color change mostly toward darker green colors is observed going down the Shenango. Shells darken from greenish colors in Padan and Pymatuning Creeks, to brownish colors where they enter the Shenango. Characteristic primary colors are Buffy Citrine in French Creek, Olive colors in the Shenango. As a whole the Allegheny Tribs. stand out for brownish colors; the Beaver for Olive, green, or yellow.

In Lake Erie

Presque Isle possesses colors not found in the Maumee which drains into L. Erie. Conneaut Lake as compared with L. Erie has yellowish rather than brownish epidermal tints.

Rays of Epidermis

Simpson—"often faintly rayed." 34 of the 69 shells showed raying persisting at least until the 8th estimated year. Rays were distinctly medium in testure when compared with those of other species, and were most widely distributed in creeks. The prevailing color was Brownish Olive, and the oldest age recorded was 8 years.

Relation of Epidermal Colors to Estimated Age of Animals.

Bluish green is most common in young shells, decreasing with age when the shells become brown, which may be an early as the 4th or 5th year. Old age colors may appear completely at 6. A brownish deposit occurs on L. Erie shells of this and other species which at times is apt to confuse the observer as to the true color. No color or group of colors seemed peculiar to any given age.

Observation on Sex-Correlative Coloration as associated with Epidermal Color. (4 shells).

Males—brownish or Yellowish Olive.

Females—green.

10.—*Eurynia recta*

SIMPSON	RIDGEWAY
Black	Bister
Olive Green	Olive, Brownish Olive, Dark Greenish Olive
	Other colors noted: (browns) Warm Sepia, Snuff Brown, Mummy Brown.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (54 shells).

Olive	30%
Warm Sepia	20%
Snuff Brown	20%
Bister	20%
Brownish Olive	10%

Distribution of Colors as a Whole in Upper Ohio Drainage (33 shells).

Mummy Brown	30%
Olive	20%
Snuff Brown	20%
Warm Sepia	10%
Brownish Olive	10%
Dark Greenish Olive	10%

Distribution of Colors as a Whole in Upper Ohio Tributaries.

	Allegheny Tribs.	*Allegheny River*	*Ohio River*	*Tuscarawas River*
Mummy Brown	16%		20%	
Olive	16%	25%	20%	
Snuff Brown	16%	25%	20%	
Warm Sepia	16%	25%	20%	
Brownish Olive		12%	20%	50%
Dark Greenish Olive	32%	12%		50%

Distribution of Colors as a Whole in L. Erie—Localities.

Chestnut	20%

Olive Ochre	20%
Brownish Olive	20%
Carob Brown	20%
Bister	10%
Dark Greenish Olive	10%

Distribution of Colors in L. Erie—Localities.

	Cedar Point	*Presque Isle*
Chestnut	33%	16%
Olive Ochre	33%	33%
Brownish Olive	16%	16%
Carob Brown	16%	16%
Bister		16%

Deductions from Tables of Percentages, etc.

Browns are in excess in the Upper Ohio as compared with L. Erie. Olives and golden yellow hues are peculiar to L. Erie.

In the Upper Ohio Drainage

For a great part of the Allegheny's course a darkening may be seen in the primary color from greenish to olive and brownish colors. The series from French Creek and the Ohio apparently do not conform to the general rule. More positive evidence can only be secured with a larger number of shells. Dark Citrine could be termed a characteristic primary color for the Ohio, Yellowish Citrine for French Creek. We may note at any rate, that the darker colors are more abundant in the tributaries than in the rivers and vice-versa, while browns are more abundant in the Ohio than in the Allegheny.

In Lake Erie

Browns are most numerous at Cedar Point, while Presque Isle has the larger proportions of black colors.

Rays of Epidermis

6 of 54 shells showed raying persisting until the 15th year. They were coarse in the specimens examined and appeared only in those from rivers. Their color was Greenish Olive, and the oldest age to which they persisted was 16 years.

Relation of Epidermal Color to Estimated Age of Animals.

Juveniles of this species are mostly green. Darkening may occur as early as 7 years and is complete at 14. No color or group of colors seems peculiar to any given age.

Observation on Sex-Correlative Coloration as related to Epidermal Color. (45 shells).

Males are Greenish-Olive in younger stages. Snuff Brown when old. Females are Brownish Olive when young, becoming darker blackish brown with age.

11.—*Lampsilis luteola*

SIMPSON	RIDGEWAY
Straw Colored	Olive Lake
Yellowish	Buffy Olive
Greenish yellow	Ecru Olive
Brown when old.	Brownish Olive, Light Brownish Olive.

Dristribution of Colors as a Whole in the Upper Ohio Drainage and L. Erie (289 shells).

Brownish Olive	30%
Ecru Olive	20%
Buffy Olive	20%
Olive Lake	20%
Light Brownish Olive	10%

Distribution of Colors as a Whole in the Upper Drainage (187 shells).

Buffy Olive	30%
Olive Lake	20%
Brownish Olive	20%
Ecru Olive	10%
Light Brownish Olive	20%

Distribution of Colors as a Whole in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Alle'ny River*	*Monong. River*	*Monong. Tribs.*	*Ohio River*	*Beaver River*	*Beaver Tribs.*
Buffy Olive	8%		25%	25%	25%	50%	10%
Olive Lake	32%	50%	25%	25%			30%
Brownish Olive	4%			25%	25%		50%
Ecru Olive	32%	25%	50%	25%	25%	25%	10%
Light Brownish Olive	24%	25%			25%	25%	

Distribution of Colors as a Whole in L. Erie (111 shells).

Mars Brown	30%
Olive Lake	20%
Dark Olive Buff	20%
Buffy Olive	20%
Ecru Olive	10%

Distribution of Colors in L. Erie—Localities.

	Conneaut Lake	*La Plaissance Bay*	*Presque Isle*	*Chautauqua L.*	*Maumee River*
Mars Brown			25%		
Olive Lake	25%	25%	25%	25%	
Dark Olive Buff	25%	50%		25%	50%

Buffy Olive	25%	25%	25%	25%	25%
Ecru Olive	25%	25%	25%	25%	25%

Deductions from Tables of Percentages, etc.

L. Erie shells have greater proportions of Buffs and Yellows. Browns are more numerous in the Upper Ohio.

In the Upper Ohio Drainage

Shells lose their green color and become more yellowish descending the Allegheny. This is also mostly true of the French Creek, Crooked Creek, Shenango and Mahoning Rivers. The distinction is not clear cut between the Monongahela River and its Tribs. but is in the case of the other rivers and their tributaries which as the tables of percentages show have yellow rather than greenish colors characteristic. Changes in secondary colors are also not well marked. This species and *L. ovata* do not readily darken in the river. Characteristic primary stream colors are Yellowish Citrine for the Allegheny, Olive Lake for French Creek, Buffy Citrine for the Shenango, Light Brownish Olive for the Mahoning.

In Lake Erie

The Maumee River, (draining into L. Erie) as well as its near locality; La Plaisance Bay has a preponderance of buff colors. Presque Isle possesses more browns and olives. Chautauqua and Conneaut Lakes resemble Presque Isle in the distribution of color.

Rays of Epidermis

Simpson—"Normally showing bright rays throughout." 203 of 289 shells were rayed. Fine rays were most abundant in L. Erie, coarser ones in the rivers, medium ones in creeks. The oldest age to which they persisted was 24 years, although such an age estimated by counting the winter rings seems a little long for a color to persist in a mussel. Coarse rays were most abundant in male shells, fine in females. They persisted in all ages of the animals.

Relation of Epidermal Color to Estimated Age of Animals.

Juveniles are Yellow or Greenish Yellow, percentages of the former decreasing, that of the latter increasing with age. Greenish Yellow is perhaps always the more abundant color. Browns and blacks appear as early as the estimated 10th year in the Upper Ohio, and somewhat earlier in L. Erie. "Old age" colors as a rule are not abundant in this or in the following species. No color or group of colors seemed peculiar to any given age.

Observation on Sex-Correlative Coloration as Associated with Epidermal Color. (140 shells)

Young males are yellow green with maturity becoming brownish green. Young females are Buffy Olive in color, with age becoming a greenish gold, (Olive Lake.)

12—*Lampsilis ovata*

SIMPSON	RIDGEWAY
Greenish	Olive ochre
Greenish yellow	Brownish Olive, Colonial Buff.
Brownish	Buffy Olive, Mars Brown, Bister, Saccardos Umber, Buffy Citrine, Ecru Olive.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie (214 shells).

Ecru Olive	20%
Buffy Olive	20%
Brownish Olive	20%
Colonial Buff	20%
Buffy Citrine	20%

Distribution of Colors as a Whole in the Upper Ohio Drainage (188 shells).

Ecru Olive	20%
Buffy Olive	20%
Olive Ochre	20%
Brownish Olive	20%
Bister	10%
Saccardos Umber	10%

Distribution of Colors as a Whole in the Upper Ohio Tributaries.

	All'y Tribs.	*All'y River*	*Ohio River*	*Ohio Tribs.*	*Beaver River*	*Beaver Tribs.*
Ecru Olive	25%		25%	20%	25%	12%
Buffy Olive	25%	25%	25%	20%	25%	12%
Olive Ochre	20%	50%	25%	20%	50%	25%
Brownish Olive	25%	25%	25%	20%		37%
Bister	5%					12%
Saccardos Umber				20%		

Distribution of Colors as a Whole in L. Erie (26 shells).

Colonial Buff	30%
Buffy Olive	30%
Brownish Olive	20%
Buffy Citrine	10%
Mars Brown	10%

Distribution in L. Erie—localities, and Chautauqua Lake.

	La Plaisance Bay	*Cedar Point*	*Presque Isle*	*Chautauqua Lake*
Colonial Buff	50%	50%	50%	

Buffy Olive	25%	25%	50%
Brownish Olive	25%	25%	25%
Buffy Citrine	25%		
Mars Brown		25%	
Dark Olive Buff			25%

Deductions from Tables of Percentages and Pl. III.

Yellow and Yellow Green colors are prominent in L. Erie; browns in the Upper Ohio.

In the Upper Ohio Drainage

A tendency to darken both in primary and secondary colors is seen descending the Allegheny—from yellowish to brownish or buff colors. This is the general change found also in the course of the Crooked and Neshannock Creeks; Ohio, Shenango and Mahoning Rivers. In most cases the shells of the tributaries will be found to have lighter colors than those of the main streams. Characteristic primary stream colors are Olive Lake in the Allegheny, Isabella Color in the Ohio, Olive Ochre in the Shenango, Olive Yellow in the Mahoning, Buffy Citrine in the Little Beaver.

In L. Erie

Yellows appear to be equally abundant at all the lake stations given, but these differ in their proportions of Buffy and Brownish Colors. Chautauqua Lake seems characterized by an abundance of the former. As was found with nacreous color, this and the last named species show little variation in epidermal color.

Rays of Epidermis

Simpson: "Broad bright green rays, wanting in older shells." 140 of 180 shells were rayed. Coarse rays were most abundant in lake specimens, medium and fine rays in the rivers, with coarse and medium textures about equally divided in the creeks. Colors, yellow to dark green, with a tendency toward black in the Upper Ohio Drainage. Coarse and fine rays are most abundant in male shells; medium in female.

Relation of Epidermal Color to Estimated Age of Animal.

No juveniles were comprised in the material worked with. Green is most abundant in shells beneath 12 years of age. Greenish yellow appears to increase in older shells in both L. Erie and the Upper Ohio Drainages. Shells may become brown or black as early as 11 years, although such colors are not abundant in either of the Lampsiline shells possibly due to their more highly polished epi-

dermis. No color or group of colors was found to be peculiar of any given age.

Observation on Sex-Correlative Coloration as associated with Epidermal Color. (106 shells).

Greenish gold colors, (Olive Lake) appear to predominate in males. Less of green and more of brown are to be found in females.

VI.—Conclusions.

1. In the species of Najades dealt with, there exists a wider range of variation of epidermal color than that indicated by standard specific descriptions.

2. In practically all the species dealt with, a decided change of epididermal color is observed going down stream from the headwaters to the mouth. The usual tendency is for the primary epidermal, or ground color to darken from an Olive Green or Olive Gray shade to Brownish or Buffy Colors, and this darkening is true in part of all colors of the epidermis, whether due to inherent causes or to those associated more with environmental causes. Within the limits of the material dealt with it is further recognized that a darkening of the epidermis may occur with advanced maturity or old age, which is quite independent of the geographical locality, but such colors are always darkest in specimens from furthest down stream.

3. The shells of L. Erie have in general lighter epidermal colors than those of the Upper Ohio and Maumee Drainages. Lighter yellows, browns and greens are more common among them, and in this respect they resemble the smaller tributary streams of the Upper Ohio Drainage. The shells of Conneaut and Chautauqua Lakes have much the same relation as those of L. Erie. Other conclusions, not however as completely substantiated as those given above, but still sufficiently evident from the present data as to deserve mention are,

4. Each drainage leaves its own imprint on the shells collected from it in the additional form of an associated or peculiar hue of epidermal color, as has already been shown with regard to nacreous and certain other physical characters of the shell. While the same general hue may be present in different drainages, these may be characteristically differentiated when necessary by the presence of varying proportions of other colors.

5. As a rule, the color distinctions may be carried so far as to

say tentatively at least that certain shades of epidermal color are characteristic even of different parts of a given locality.

6. The rays of the epidermis disappear with age and have in the limits of the material worked with, their widest distribution is specimens from small rivers and creeks.

7. With regard to the relation of epidermal color to the estimated age of the animals, it was found that no one color or group of colors was peculiar to a given age of the animals, except the yellowish or grayish colors of early youth, or the deep browns and blacks of old age and advanced maturity.

8. The epidermis of most species shows clearly defined sex-correlative coloration.

VII.—Suggestions as to Causes of Facts.

Introductory remarks embody the writers comments on the first of these conclusions. In view of the evidence presented, the most plausible explanation of the second would seem to be found in the physical and chemical conditions under which the shells live. A summary of the more outstanding physical and chemical conditions in the Upper Ohio Drainage and L. Erie has been previously given.

A physical condition which may seem closely related to the problem of epidermal color is the warmer temperature of the water in the former, for it has been shown that the shells from the Upper Ohio possess more pigment, pigment is the result of chemical reactions, and the degree of chemical reaction in general is increased by heat.

It is readily comprehended that the problem of epidermal color is a more complicated one than that of nacreous color. The epidermis, protectory in function, is in direct contact with the environment, and is the recipient of all chemical and physical forces involved whereas the nacre, while probably the subject of all forces acting through solution, is probably interacted upon by relatively few physical forces. In a previous paper it was shown that the tints of nacreous color lighten going down stream in the Upper Ohio Drainage, and that the nacre of L. Erie shells possesses lighter hues than those of the former. Suggested causes for these phenomena were,

1. Presence of humic acid in the headwaters of streams, which with a greater amount of available light due to less amount of silt there, affords favorable conditions for the production of pigment.

2. Reaction of humic acid upon the yellow or red Fe_2O_3 of the soil or of the water, resulting in its reduction to FeO, whence FeO by interaction with CO_2 of soil water or environment becomes $FeCO_3$, a whitish or yellowish compound.* It was additionallly pointed out that iron is a part of the composition of the mussel shell, and reasoning from the basis that it is known to be an important constituent of animal and vegetable pigments, it was suggested that the deeper tints of nacreous color in the headwaters was due by some similar process to the inclusion of greater amounts of Fe_2O_3 in the shell, especially since the water in the tributaries has a greater degree of oxygenation (due to greater rapidity of the current), whence the transition from carbonate to ferric oxide might be affected. In L. Erie, the nacreous colors of shells seemed more closely related to the greater degree of alkalinity of the water.

3. Further down stream, the reaction of the Humic acid upon the ever increasing amount of lime may produce CO_2. This or other available CO_2 may attact the iron oxides producing Fe_2CO_3. Under the conditions present, this latter compound may remain stable, since oxygenation, (slower current) is less, light is less due to increasing amounts of silt, and organic matter is more. Now it is also known that organic matter at times may mask the red or yellow iron oxides in clay, giving the latter a bluish, greenish or bluish, greenish or even other colors. Provided then that Fe_2CO_3 is the iron compound available downstream for mussel shells, and that there is a greater inclusion of organic matter at such localities, plausible explanation for the changes or fading out of nacreous color is found.

Much of the above may be made to apply to the problem of epidermal color also when the following is born in mind. It has been shown that the change in epidermal color is opposite to that reported for nacreous color. Under the conditions, 2 groups of factors acting separately or jointly may produce such an effect, representing as they do natural and unnatural environments of the shell.

1. In connection with the natural group, it may be pointed out that the amount of silt as well as the darkening of the epidermis increases going down stream. Further, the mussel shell is subject to constant erosion from CO_2 or other chemicals in the water

*For a full discussion of Humic acid and its relation to iron compounds see Pirsson, L. F. and Schuchert, C. S., "A Textbook of Geology."

and from the current itself, especially when the latter carries suspended matter. Darkening then might be due to the use of minute particles of the silt in the shell building activities of the animal or to their external deposition on the shell. This general proposition, that the silt is indirectly or indirectly responsible for the blackening of the shell, is borne out by the fact that in L. Erie where there is relatively less silt, the shells are lighter and clearer in epidermal colors.

If we now endeavor to relate the facts stated to those seemingly furnishing a reasonable hypothesis for the change in nacreous color, we may tentatively suggest that shells are yellow or yellowish green upstream and in the tributaries on account of the yellow oxide of iron (Fe_2O_3) they may contain. Downstream the inclusion of greater amounts and variety of organic matter in the silt darkens them as organic matter darkens clay. That the degree of pigmentation seems to depend largely on the environment colors. There appeared to be no regular sequence of development of epidermal color beyond the fact that most shells are yellowish when young, and with age become blackish or brownish. A shell from a given locality may have old age colors when it is still comparatively young, while another locality may show shells retaining juvenile colors to an advanced maturity. We have also noted that shells darken with age in the tributaries and headwaters, that is, quite independent of their geographical locality. A fair reason is presented when we combine the time element with the factors stated above, and take into consideration the physical characters of the shells. While the water in the tributaries is swifter, erosion of the shells may be slowed down, for such characters as greater compression there, (as has been confirmed by many investigators) enable it to present less surface to the eroding waters, and while silt is present it is not in abundance and variety as is the case further down stream. If silt plays any part in the coloration of the epidermis, it is evident that a longer time will be required to affect the shell, and it follows, that age for age, colors will be lighter in the tributaries than further down stream. A convenient analogy here is that applying to the bark of certain trees. The cork will become black more quickly in an industrial community under the influence of smoke or chemicals in the air, than it will in the virgin forest, but ultimately it becomes black in either locality. As the shells were first thoroughly scrubbed before making color comparisons,

it might be fairly assumed that any remaining coloration, making allowance for the possible effects of stream pollution was characteristic for the shell at the locality. Finally, the natural conditions of the Upper Ohio are also largely true of the streams draining into L. Erie, and similar explanations may be advanced for the shells living them.

2. The pollution of streams by sewage and industrial wastes presents a most unnatural factor affecting the epidermal color of shells.* While as Ortmann and Baker have independently pointed out, pollution from either source may be so extensive as to ultimately kill the animals, for the purposes of our problem we may only consider their possible relations to epidermal color. Sewage is largely organic matter and would seem first hand to be most largely concerned with the amount of silt in the stream. According to Prof. Earl Phelps of the U. S. Public Health Service, the industrial wastes are largely sulfuric acid and sulfate of iron. Where the former chemical is present in sufficient abundance it would burn the organic matter, (conchiolin) of the shell black and thus be partly responsible for darker colors, while the sulfate of iron might form discoloring deposits. As it happens that the pollution of the water by these wastes increases going down stream, undoubtedly some of the change of color indicated is due to it, at least in the lower stretches of the Allegheny and the Monongahela as conditions now stand. This deposit of iron is frequently so tenacious as to require acid to dissolve it.

The fact that each drainage leaves its own imprint on the shells collected from it is well known to experienced collectors. In view of the data previously presented with regard to the great uniformity in epidermal color determinable at a given locality, such seems readily referable to peculiar stages in the development of the environmental conditions outlined. Similarly, causes underlying conclusion 5 may be sought for. The rays of the epidermis may disappear with age on account of the darkening of the epidermis due to the causes suggested. The rays have their widest distribution in small rivers and creeks, where of course, silt is not in its greatest variety and abundance. The conclusion as stated that age has no relation to a regular sequence of epidermal color change somewhat bears out the opinion ventured concerning the greater effect of the

* The localities from which my material was collected gave evidence of pollution at the time, and a large number of them are now completely barren.

environment in determining what the epidermal color shall be. In the case of brighter hues of nacreous colors in females, such a finding with regard to the epidermal color may also be safely regarded as a "metabolic accident."

VIII.—Relative Variation in Epidermal Color in Species Dealt With.

The shells were so unevenly distributed with regard to localities that it was impossible to determine those places where the greatest amount of variation in epidermal color took place. Some idea may be obtained from Pl. III, when such is studied from the standpoint of any great body of water as a whole. In an effort to make a partially balanced determination of the relative variability of epidermal color among them, a rough and arbitrary comparison was taken by dividing the number of "relative colors" observed in each shell by the number of that species examined. From this data, it seems that within the limits of this investigation that the larger number of shells is apparently associated with less variation in epidermal color. At the same time the results are hardly fair for those species represented by a small number of specimens. Results from this method show the relative variability of the shells to be as indicated in the following table. The small numerals following the name of each species indicate its order in range of variation of nacreous color similarly determined. (4). and from it a convenient comparison of the relative variability of epidermis and nacre may be taken.

Species	*No. Relative Colors taken*	*No. of Shells*	*Factor Calculated.*
1. Eurynia recta (1)	45	54	.83
2. Proptera alata (2)	42	55	.76
3. Anodont. ferussacianus (6)	45	69	.65
4. Paraptera fragilis (3)	33	58	.56
5. Anodonta grandis (7)	54	119	.43
6. Symphynota costata (11)	31	63	.41
7. Lampsilis ovata (9)	62	214	.28
8. Amblema plicata (5)	59	185	.27
9. P. obliquum coccin. (4)	59	263	.22
10. Lampsilis luteola (12)	63	289	.21
11. Fusconaja flava (8)	42	275	.11
12. Elliptio dilatatus (10)	65	561	.11

If, in view of difficulties the reader will comprehend were encountered in organizing this type of data, 2, (or in some cases 3) ranks in the above table on Relative Variation of Color is allowed

for inaccuracy of color determination, it will be seen that variability in epidermal color is closely associated with that of nacreous color.

Sources of Error.

The Ridgeway Color Nomenclature was used with careful consideration of the directions given in it. It may well be urged that the sense of color is so varied in its development among humanity that results of this kind may not have the same significance for all interested in such problems. But the same criticism could be applied to the ornithologist who uses the Nomenclature continually. The writers confidence in his own observations is largely based on the fact that U. S. Army Tests have shown his vision to be normal in every way.

It is also true that at times, the mussels migrate from place to place in the same stream, and probably from the rivers into the tributaries. Where a small number of shells were used in making comparisons this might have some effect on the results obtained, but as the evidence of most observers is that migration is comparatively rare among them, this can hardly have any effect on the general impressions this paper hopes to convey, indeed, they might be held to account for discrepancies which will be observed here and there. Finally, pollution of streams by sewage, industrial waste, erosion by gravel and water etc., may be so extensive as to produce a color in some cases thoroughly unnatural to the animal. A check which covered most of these cases was the primary color taken which part being usually buried in the mud, would be more immune to such influences, and apt to show its truest tints.

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